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This thesis reflects on the historical origins of the dissimilar air-to-air adversary concept and makes comparisons to today's U.S. Navy and Marine Corps adversary forces. This investigation focuses on the cost effectiveness of dedicated adversary aircrews and platforms in providing air combat maneuvering training in comparison to utilizing front-line fleet airframes and aviators for this mission. The examination also considers the current adversary capability within the Department of the Navy (DON), discusses possible solutions to overcome the DON "Red Air" deficiency, and makes recommendations for material upgrades to improve the DON adversary capability writ large.

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MASTER OF MILITARY STUDIES

Check Six: Take a Look Back (Again) to Ensure Future Fighter Success

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
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Major Kevin A. Campbell
United States Marine Corps

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TABLE OF CONTENTS

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Preface

During my last fleet F/A-18 squadron tour a disheartening thought dawned upon me—that the woeful deficiency in Marine adversary platform capability and numbers not only robbed fleet aircrews of precious training opportunities, but also drove them to complacency, mediocrity, and a false sense of security. I was also saddened to think that this deficiency could ultimately cost lives—both in the air and on the ground—if our country ever goes to war with a nation possessing a near peer air force capability. While I was pondering the idea of writing about this subject for my master's thesis when I first arrived at Command and Staff College, it was not until I received a briefing on the Marine air plan in November 2010—which failed to mention VMFT-401's existence beyond 2015—that I realized how dire the situation truly is. My hope writing this paper is that I may inform others of the plight of Marine (and Navy) adversary squadrons, and the important role they fulfill which justifies their existence.

I would like to acknowledge those Naval aviators who encouraged me to research and write about this contemporary issue—Major Travis Russell of VMFT-401, LCDR Scott Seeder of VFC-12, and LT John Peterson of TOPGUN. Without the support and primary source information from Scott and John, I probably would not have undertaken this research paper. I am also grateful to my faculty advisor, Dr. Paul Gelpi, for the thoughtful guidance and patient assistance he provided and to Lt. Gen. Paul K. Van Riper, USMC (Ret) for his thought provoking viewpoints and insightful thoughts on Red Teaming. Additionally, I would like to thank Rachel Kingcade for research assistance as well as Dr. Patrice Scanlon and the Leadership Communications Skills Center personnel for their writing assistance throughout the academic year. Finally, I offer a special thank you to my fiancé, Alissa, without whose understanding support and encouragement I would not have persevered so diligently to complete this project.

EXECUTIVE SUMMARY

Title: Check Six: Take a Look Back (Again) to Ensure Future Fighter Success

Author: Major Kevin A. Campbell, United States Marine Corps

Thesis: As the only unit chartered to provide adversary capability to Marine Corps tactical aviation, VMFT-401 offers an invaluable tool for the combat preparation of fleet aircrew and an efficient utilization of scant resources. However, the squadron will remain effective, as an accurate threat replication and fleet training aid, only if upgrades to airframes occur to meet the needs of current and future fleet combat preparation requirements.

Discussion: Since the dawn of aviation, militaries have employed airplanes in the conduct of war to effect enemy forces both on the ground and in the air in order to achieve desired operational results and further political goals. Although the United States has historically sought technological solutions to gain air superiority against less technologically advanced foes, history has shown that training—especially dissimilar air combat training (DACT)—has been more influential than technology at influencing the outcome of air-to-air engagements. Navy aircrews in Vietnam demonstrated this fact well in the dramatic turn of events following the introduction of improved DACT methods and the formation of the Navy Fighter Weapons School.

Proven as a successful concept in Vietnam, formal adversary squadrons entered service in 1973, employing dissimilar airplanes that accurately represented those of threat countries to challenge fleet aviators in air-to-air combat. Unfortunately, the Navy and Marine Corps have done little since then to enhance adversary capability or capacity. They have relegated the performance of many adversary missions to untrained fleet aviators who fly costly front line fighter aircraft when the antiquated adversary aircraft permanently assigned those missions are not available. This delinquency results in cost inefficiencies, training deficiencies, and the development of an air-to-air force that is ill prepared. This examination considers the current adversary capability within the Department of the Navy (DON), makes comparisons of possible solutions to overcome the "Red Air" deficiency, and makes recommendations for material upgrades to improve the DON adversary capability writ large. Although the author acknowledges the existence of burgeoning unmanned systems involved in air-to-air combat, this system is outside the scope of this study and therefore not addressed.

Conclusion: The Red Air community must not only sustain and upgrade its antiquated airframes, but must also seek new technologies, capabilities, and capacity. Through judicious utilization of scant resources, the Department of the Navy must keep its adversary programs relevant, affordable, and threat representative in order to prepare today's aircrew adequately for success in tomorrow's air-to-air combat environment, or risk losing air superiority.

INTRODUCTION

"A gentleman said: 'To rely on rustics and not prepare is the greatest of crimes; to be prepared beforehand for any contingency is the greatest of virtues.'"
-Ho Yen-hsi, on Sun Tzu's observation that, "He who is prudent and lies in wait for an enemy who is not, will be victorious."[1]

At present, the United States' military has the ability to affect operations on the ground in Iraq and Afghanistan at the time, place, and nature of its choosing because of its aviation assets. Although U.S. aviators established air supremacy in these countries without interference from enemy air forces, this situation has not been and arguably will not always be the case. To achieve air superiority, if not air supremacy, current and future aviators must maintain their proficiency in air-to-air (A/A) combat, which includes the pilot's ability to maneuver (evade and attack) against the enemy. Air Combat Maneuvering (ACM) is a crucial element in A/A combat; and, experience fighting a dissimilar adversary is the primary method to achieving maneuvering prowess because they employ aircraft that replicate weapons systems that are often, but not always, aircraft of Russian or Chinese origin.[2] Practicing dissimilar air combat training (DACT) helps fighter pilots to hone their skills by learning to maximize the advantages of their airframe, while minimizing the strengths of opposing aircraft.

Marine F/A-18A/C/D aircrews conduct DACT with U.S. Navy and Air Force aircrews, foreign aircrews, and adversary squadrons during exercises, but have a large deficiency in DACT support required to meet all training requirements dictated by the F/A-18 Training and Readiness Manual (T&R).[3] At present, the USMC maintains only one adversary squadron, Marine Fixed Wing Fighter Training Squadron 401 (VMFT-401).[4] Yet, VMFT-401 must provide professional, dedicated airborne adversary presentations and threat replications to Marine aircrews with the obsolete F-5E/N Tiger II. Despite flying aging airframes with outdated avionics and weapons

suites, the Marine adversary aircrews of VMFT-401 train untested Marine aircrews in DACT prior to engaging enemy aircraft in combat in order to provide them with the A/A combat experience necessary for Marine aircrew to establish air superiority.

If the second-generation jet, F-5E/N, remains the only Marine adversary aircraft, then VMFT-401 will be unable to accurately replicate the capabilities and tactics of opponents flying fourth generation or newer jet fighter aircraft. With Marine aircrews flying fourth generation jet fighters, the squadron's ability to execute its mission is debatable; a situation that is also magnified by the arrival of fifth generation fighters in the fleet, as well as in opponents' air forces. As the only unit chartered to provide an adversary capability to Marine Corps tactical aviation, VMFT-401 offers an invaluable tool for the combat preparation of fleet aircrew and is an efficient utilization of scant resources. However, the squadron will remain effective, as an accurate threat replication and fleet training aid, only if upgrades to airframes occur to meet the needs of current and future fleet combat preparation requirements.

The remainder of this paper examines the historical origins of the adversary training concept with considerable focus on initiatives conceived during the Vietnam era. This narrative also discusses the current state of adversary capabilities within the Navy and Marine Corps. It likewise addresses options to overcome the hurdles preventing improvement of the Department of the Navy adversary force writ large. Finally, this paper recommends ways to improve the Navy and Marine Corps adversary capability based upon cost and effectiveness of these options.

ORIGINS OF THE ADVERSARY TRAINING CONCEPT

World War I and World War II

As early as World War I, those who waged war recognized the value of aerial reconnaissance and the effectiveness of air delivered ordinance on their enemies. As such,

gaining air superiority became a focus of air forces as aircrews began to engage one another in the skies above Western Europe. Both sides developed fighter tactics to pit friendly aircraft strengths against assessed enemy aircraft weaknesses. Consequently, German Air Commander Oswald Boelcke devised a program to rebuild captured enemy aircraft to make accurate assessments of their flying capabilities through actual flight tests, which greatly contributed to tactics development and inadvertently spawned the adversary aircraft concept.[5]

Similarly, at the beginning of U.S. involvement in World War II, U.S. aviators faced the more capable Japanese Zero in the battle for air superiority in the Pacific Theater. Unable to overcome the performance difference between the Zero and the inferior U.S. aircraft (e.g., F4F Wildcat), U.S. pilots turned to dissimilar air combat tactics (DACT) development while awaiting the production of more capable U.S. aircraft. U.S. Navy Lieutenant Commander Jimmy Thach used two unevenly powered F4Fs to simulate the performance imbalance between the F4F and the Zero to test and validate the effectiveness of his weaving tactic against a superior performing aircraft without actually employing the aircraft he designed the tactic to defeat. As a result, Thach's new tactic led to many combat successes and further demonstrated that the "dissimilar" tactics development concept provided much utility to U.S. aviators—a utility they exploited further in peacetime.[6] (For more on WWI and WWII, see Appendix A)

Korean Conflict

When the Soviets introduced the MiG-15 in the skies over Korea, the U.S. Navy had a mix of comparably inferior propeller driven and jet driven aircraft fighting in the conflict. As a result, Navy and Marine aircrews flew fewer A/A missions than the Air Force due to their hodgepodge of aircraft, which included only limited numbers of jet aircraft to assign to A/A

missions.[7] Yet, as jet aircraft numbers and capabilities improved, so too did innovation in tactics development and training.

The F-86 Sabre was the U.S. answer to the MiG-15 and was comparable in most respects. Each aircraft possessed capability advantages such as maximum ceiling, top airspeed, sustained turn rate, instantaneous turn rate, low altitude performance, and slow speed handling in different flight regimes. Thus, the experience of the pilot at the controls of the aircraft, his knowledge of the adversary's strengths and weaknesses, and the conditions under which the engagement began ultimately determined the outcome of each engagement.[8] Since the relative strengths and weaknesses of each aircraft were negligible, the conditions at the start of the engagement and the experience level of the pilots who controlled the aircraft were the keys to success. U.S. aviators consequently focused on A/A training because it could also most easily affect these two factors. Thus, the overall superior training of U.S. aircrews relative to North Korean Air Force pilots, coupled with the high percentage of World War II experienced U.S. aircrews, tipped the scales in favor of U.S. forces, resulting in a remarkable twelve to one kill ratio overall.[9]

Vietnam Conflict

As technology advanced and aircraft and avionics design improved, U.S. aviators also altered dissimilar tactics. The advent of advanced aircraft equipped with onboard radar systems and radar guided missiles such as the F-4 Phantom equipped with the AIM-7 "Sparrow" air-intercept missile caused the emphasis in A/A combat to shift from close in "dogfight" training to longer range, forward quarter missile engagements. The U.S. belief that forward quarter missile engagements would allow fighter aircrews to destroy enemy aircraft beyond visual range (BVR), or before either aircrew gained sight of their opponent, triggered U.S. forces to largely ignore within visual range (WVR) A/A combat training as the Vietnam Conflict began. Thus, the U.S.

entered Vietnam in 1964 with only the Navy pilots who flew the F-8 Crusader, an aircraft that was not equipped with radar guided missiles, continuing to practice WVR maneuvering, also known as dogfighting.[10]

The fielding of the F-4 and increased focus on BVR tactics by the USN and USAF in 1961, coupled with restrictions on dogfight training due to noise complaints and aircraft mishaps, also limited the emphasis placed on close in engagement training. Although the Navy created specialized gunnery instruction units, Fleet Air Gunnery Units (FAGU), to develop pilots' skills in air-to-ground gunnery, it established no such institution to increase air-to-air proficiency. This discrepancy was largely due to technologically fueled overreliance on BVR doctrine and subsequent abandonment of the A/A gun concept. As a result, many U.S. Navy pilots employing the F-4 Phantom lacked WVR DACT experience, much less proficiency, when faced by North Vietnamese aviators. Consequently, the U.S. Navy scored a paltry F-4 A/A kill ratio of 2 to 1 through 1968 in comparison to the Navy's overall 10 to 1 kill ratio in Korea.[11] Conversely, the "Sparrowless" F-8 Crusader accounted for 19 MiG kills with only 3 Crusader losses by 1967.[12]

Ault Report

To determine the root causes of the inferior performance of Phantom crews and their associated missile systems in Vietnam, the Navy ordered Captain Frank W. Ault, USN, to conduct an in-depth review of F-4, F-8, AIM-9 Sidewinder, and AIM-7 Sparrow procedures, training, and employment practices from cradle to grave.[13] Thus, the Navy inspected and evaluated the Phantom and its associated weapons systems from acquisition, to fleet integration and training, through end user employment.[14] In what became known as "The Ault Report," Captain Ault and his Navy team of inspectors reported that many factors contributed to the lackluster performance of the F-4 specifically. These factors ranged from Rules of Engagement

(ROE), which limited BVR employments; aircraft ergonomics deficiencies; missile to aircraft interface problems (in the case of the AIM-7 Sparrow); immature missile technologies; missile handling procedure imperfections; and most importantly, because it could be immediately affected, insufficient A/A training for Phantom aircrews. [15]

Furthermore, the investigation revealed the importance of the availability of adequate training facilities and assets to aircrew performance. Concerning training and readiness, the report noted,

> Realization of improved aircrew performance should be possible through increased missile and target allowances, better range facilities, more realistic air combat maneuvering training, a concentrated effort on aircraft missile system qualification (as well as aircrew firing qualification), and improved tactics and doctrine.[16]

The report also advised the Navy to consolidate and promulgate fighter tactics training by commissioning an "Advanced Fighter Weapons School" at NAS Miramar for F-4 and F-8 aircrews.[17] The Navy established the advanced school, which held its first class on March 3, 1969, and became known as the Navy Fighter Weapons School, or more commonly, TOPGUN.[18]

TOPGUN

The newly created Navy Fighter Weapons School intensely focused on dissimilar air combat training and tactics through a rigorous syllabus combining academic and flying facets. During the flight training, instructors exclusively flew dissimilar aircraft as a necessary requirement to force students to pay close attention to the adversary aircraft in order to capitalize on its weaknesses. As Navy and Marine aircrews began to cycle through TOPGUN and take their newly acquired knowledge and skills back to the fleet as air combat tactics instructors, the Navy fighter community's A/A proficiency significantly improved. Both TOPGUN and fleet squadrons increasingly made improvements in teaching methods using techniques such as "chalk

talks," or lectures utilizing a chalkboard to explain key facets of ACM. Similarly, improved assets appeared. Air Combat Maneuvering Instrumentation (ACMI) pods allowed for digital re-creation of flights, and upgraded gun camera and radar screen recorders provided for more detailed aircrew performance debriefs.[19]

The Navy Fighter Weapons School's instruction directly contributed to improvements in training and debriefing methods, and as such, "the TOPGUN program was credited with dramatically improving the F-4 community's performance [in combat]. By 1972, the Navy's kill ratio had soared to a 12:1 loss ratio."[20] This dramatic turn of events in the Vietnamese air war validated the findings of the Ault Report, served as one basis for forming the Navy's first formal adversary squadrons in 1973, and helped secure the permanence of the Navy Fighter Weapons School as its own entity.[21] (For USAF analysis of the Vietnam Conflict, see Appendix B)

Top Off, Red Baron,* and *Have Doughnut

As A/A hostilities concluded in Vietnam, USAF veteran pilots concerned themselves with A/A tactics because although by 1972 the Air Force had downed 50 MiGs to the Navy's 24, the Air Force kill ratio dropped slightly since 1968 to about 2:1 overall, in contrast to the Navy's improvement in kill ratio to 12:1. In recognition of the TOPGUN program's achievements, the Air Force responded in 1972 by changing aspects of the flying curriculum at its Fighter Weapons School located at Nellis Air Force Base, Nevada. This revised syllabus, known as *Top Off*, involved 13 ACM flights with a large emphasis placed on DACT.[22]

Even still, when invited to participate in *Top Off*, Navy and Marine fliers routinely out-performed their Air Force counterparts.[23] To correct the disparity between the services, the Air Force formed a commission in 1973 to investigate ACM more fully. In a report about the project known as "Red Baron II", the commission recommended creating dedicated "Aggressor" units

that employed tactics used by U.S. enemies to train aircrews in dissimilar air combat. The report stipulated that, "realistic training can only be gained through the study of, actual engagements with, possessed enemy aircraft or realistic substitutes."[24]

Resembling the early days of aviation in World Wars I and II, the U.S. made efforts to acquire actual threat nations' aircraft to better understand its performance characteristics in order to improve U.S. aircrew performance in combat. Consequently, the Air Force and Navy created a joint program codenamed "Have Doughnut" to exploit a MiG-21—secretly acquired by the U.S. Defense Intelligence Agency in 1967—through actual flight tests. The joint team also conducted flight evaluation of MiG-17s captured by Israel under the name "Have Drill."

Aircrew of the two services pit the F-4 against the acquired MiGs to glean knowledge in employment of the F-4 in overcoming the MiG's strengths (the F-4 conducted slashing attacks while maintaining higher airspeeds to counter the MiG-17's smaller turn radius and superior handling at slower speeds).[25] The improved performance of Navy aircrews in Vietnam reflected the value of this "Have Drill" program, along with that of the TOPGUN course. Since not all aircrew had access to threat aircraft such as the acquired MiGs to train against, yet Vietnam results proved the validity and effectiveness of the DACT concept, the Navy and Air Force formed adversary and aggressor squadrons, respectively.

The USAF embraced the recommendations of the Red Baron Report in July 1973 with the formation of the 64th Fighter Weapons Squadron at Nellis AFB.[26] The Navy also formed dedicated adversary squadrons in each of its Fighter and Attack Master Jet Bases (NAS Miramar, NAS Oceana, and NAS Lemoore) to train fleet aviators in addition to stressing DACT at TOPGUN. However, the Marines were slower to join the professional "Red Air"[27] business and invested in a single adversary squadron, VMFT-401, in Yuma, Arizona, in March 1986.[28]

PRESENT STATUS OF ADVERSARY FORCES

USAF

The United States Air Force maintains an adversary capability through three active duty aggressor squadrons located at Nellis AFB and Eielson AFB, Alaska. The Air Force bases its 64th and 65th Aggressor Squadrons, which fly the F-16C Fighting Falcon and the F-15C Eagle, respectively, at Nellis. These two squadrons are chiefly responsible for providing the Red Air profiles for each "Red Flag" exercise that takes place at Nellis. (For more on Red Flag, see Appendix C) Although these squadrons do travel occasionally to provide tactical squadron level unit support (fleet support in the USN / USMC), their primary mission remains exercise support during Red Flag.[29] Likewise, the 18th Aggressor Squadron, which flies the F-16C/D at Eielson AFB, provides a DACT capability mainly in support of exercises, such as Cope Thunder, Northern Edge, and Red Flag Alaska.[30] According to the USAF construct, squadrons conduct day-to-day ACM training within the individual squadron or with sister squadrons by swapping blue (friendly) and red (enemy) roles. To gain valuable DACT, frontline USAF pilots rely on blue/red swaps with dissimilar Air Force airframes when they are co-located, with visiting squadrons from the Navy or Marine Corps, or by engaging USAF aggressor aircraft at exercises.

USN

The United States Navy flies four different platforms as adversaries. These aircraft are the F-5E/N/F Tiger II, the F-16A/B Fighting Falcon, the F/A-18A/B/C Hornet, and the F/A-18E/F Super Hornet. The Navy spreads its adversary capability amongst three geographic locations and four squadrons. Fighter Squadron Composite Twelve (VFC-12) flies the F/A-18C and resides in NAS Oceana, Virginia, while VFC-13 and VFC-111 fly the F-5E/N/F and reside in NAS Fallon, Nevada and NAS Key West, Florida, respectively.[31]

In contrast to the USAF aggressor squadrons, each of these squadrons belongs to the Navy Reserve and their primary duties involve supporting fleet workup cycles. Through co-location with resident fleet squadrons at Oceana, cross-country training detachments to Lemoore, CA, and by hosting visiting fleet squadrons and Fleet Replacement Squadrons (FRS) in Fallon and Key West, the Navy adversary squadrons provide critical ACM training. Additionally, squadrons at Fallon and Key West provide DACT to fleet aviators. As in the Air Force construct, the Navy conducts additional ACM "in house," and through soliciting red/blue swaps with fellow Navy, Marine, and Air Force units.[32]

USMC

Because the United States Marine Corps (USMC) provides its Red Air capability to the fleet through its sole adversary unit, the VMFT-401 Snipers, its adversary squadron construct is unique. As a Marine Corps Reserve unit home based in Yuma, Arizona, VMFT-401 employs the F-5E/N Tiger II and mixes the Air Force "exercise only" mentality with the Navy "fleet support" ideology, thus providing *both* exercise and fleet support. As the principal adversary platform at the bi-annual Weapons and Tactics Instructor Course (WTI) hosted by Marine Aviation Weapons and Tactics Squadron One (MAWTS-1) at Yuma, the Snipers provide realistic, accurate threat representations to aviators destined to become training officers in their fleet squadrons upon completion of WTI. Additionally, VMFT-401 travels to provide the majority of Red Air aircraft in support of the bi-annual Marine Division Tactics Course (MDTC), which generally occurs at MCAS Miramar, California, or MCAS Beaufort, South Carolina. The Marine adversaries also provide threat replication and adversary tactics instruction to Marine Corps Fleet Replacement Squadron (FRS) aviators who are learning to fly the F/A-18A-D. The

Snipers also conduct excess sorties as needed for fleet Marine squadrons located at MCAS Miramar, or on detachment to NAS El Centro, California or Yuma in the fleet support role.[33]

Current Adversary Posture

Capability and Quantity

Although the collective airborne adversary capability of the United States Armed Forces is alive today, it is far from well. Specifically, the USN and USMC adversaries lack threat representative aircraft and quantity of flyable airframes. With the exception of new NSAWC F/A-18E/Fs, the current adversary fleet employs aging airframes, outdated avionics, and limited radar capability to simulate advanced threats. Additionally, only the "slick"[34] NSAWC F-16A/B can truly simulate the speed, altitude, and handling capabilities of advanced enemy fighters that DON adversary aircraft intend to replicate, but only 19 reside in the Navy's inventory.[35]

The DON's most plentiful adversary asset (44 airframes) is the once venerable, but now practically obsolete, F-5E/N/F, which has limited radar capability, small fuel capacity, no video recorder capability, and bore sight only infrared (IR), or heat seeking weapons. In fact, the F-5E/F was relatively limited in capability when its production ended in 1987, and the newer F-5N which was later integrated into the adversaries' fleet, have no more capability although they were built in 2003 and boast limited upgrades. The current Marine Corps adversary capability is limited to F-5s only, with a total of 12-13 (of the DON total of 44) airframes on hand. As such, VMFT-401 "F-5s provide only 32% of Marine units 'Red Air' sortie requirements" [36] leaving the remainder to be flown in-house or through red/blue swaps. The requirement is similar for the Navy, which flies approximately 60% of fleet Red Air requirements with "blue" assets (fleet squadron airframes).[37] In total, Navy and Marine fleet squadron F/A-18s fly approximately 9,000 and 7,400 annual adversary sorties respectively.[38]

Cost Effectiveness

When assessing adversary requirements, in addition to quantity and quality (capability) of adversary airframes, there is a third point to consider, cost effectiveness. In a perfect world, the adversary force would be composed of the most threat-representative aircraft in abundant numbers, but that is simply not reality. Cost efficiency is more important than ever. Budgets are shrinking and congress has terminated even multiyear, multi-billion dollar programs with billions of dollars already invested in them such as the Expeditionary Fighting Vehicle (EFV) and F-22 Raptor.[39] Thus, DON support of over sixty percent of Red Air requirements with blue assets is simply not cost effective for a number of reasons.

First, even within the current adversary capability of the USN the F/A-18 is the most costly to operate. This is true both in fuel and maintenance cost per flight hour, at approximately 225% of the F-5N cost per flight hour (CPFH) and approximately 150% of the F-16A/B CPFH.[40] (See Appendix E, F) Thus, any active component, fleet owned, blue F/A-18s flown in the Red Air role are just as costly as those reserve VFC-12 F/A-18s permanently assigned the adversary mission when compared to "cheaper" red assets such as the F-5.

Second, many hidden costs exist associated with flying blue assets (in this case legacy F/A-18s specifically) in the Red Air role. Every sortie flown in a Red Air "support" role reduces the number of blue sorties available to train fleet aviators by one. In addition, each flight hour logged flying Red Air reduces the number of flyable hours on that fleet airframe by one. This reduces the amount of Blue Air sorties that aviators can ultimately fly with that airframe. These hidden opportunity costs on fleet aviator training and airframe life are significant when totaling over 9,000 flight hours per year. Since each Hornet is planned to fly for 8,600-10,000 hours

(extended twice from its originally planned 6,000 hour rating), the Navy and Marine Corps spends the lifespan of roughly two fleet Hornets each year simply by flying adversary missions.[41]

With much thought given to preserving the life of fleet assets, the Marine Corps has imposed several restrictions in recent years on fleet aviators and the training they conduct in order to manage F/A-18 airframe wing root fatigue life expenditure (FLE). In addition to limiting the maneuvering allowed in certain sorties, USMC initiatives instruct aircraft maintainers to evaluate airframes for remaining wing life and manage FLE aggressively by pairing aircraft with high FLE rates to sorties that demand less wing loading and airframe stress. Yet, the fleet continues to sacrifice airframes out of necessity to perform Red Air missions to the detriment of the Hornet fleet as a whole, a costly venture considering that the legacy Hornet is no longer in production and expected to fly through fiscal year 2025.[42]

A final hidden cost of fleet aviators flying Red Air roles in blue airframes lies in the human domain and is two-fold—negative training for the aviators flying Red Air, and a typically less accurate threat representation provided for the aviators executing the Blue Air mission. This is largely due to the similarity of the airframe itself. Furthermore, the "blue" aviator loses the psychological and emotional realism gained by flying against an unknown adversary when a squadron mate, who he sees and interacts with on a daily basis, performs the adversary role. Because squadron mates are less likely to know all aspects of enemy aircraft capabilities and employment procedures and are more likely to insulate their co-worker from failure, they often give a substandard presentation (when compared to that given by professional adversaries). Red Flag, which was largely responsible for Air Force successes during the 1990s, relies upon dedicated dissimilar Red Air assets and professional adversary pilots—unknown personally to the aircrews attending Red Flag—to provide the most realistic and threat representative ACM

training possible.[43] Colonel Gregory Fontenot, USA (Ret.), renowned red teamer and head of Fort Leavenworth's University of Foreign Military and Cultural Studies notes, "Threat emulation that reflects a genuine capability consistent with a given threat's potential is a critical part of the experiment or test equation."[44] Thus, anonymity of professional adversaries helps challenge the validity of developing tactics and breeds innovation through accurate threat replication.

Reasons to Keep an Adversary Capability

Maintaining a Red Air capability is important for a variety of other reasons than those previously mentioned. The most important reason is that fleet aviators gain a large training benefit by fighting a dissimilar adversary, and consequently develop A/A experience applicable in combat. For all of the same reasons that aviators considered DACT as a vital prerequisite for success in the ACM arena from World War I through Vietnam (increasing pilot A/A experience and thus likelihood of survival chiefly), dissimilar training is still a valuable component of air combat preparation today.[45] (For more information, see Appendix G)

Furthermore, a professional Red Air capability is fundamental to tactics validation and development. No computer simulation can adequately represent the myriad of options that a smart, thinking, live adversary may choose to employ based on his real-time assessment of situational factors and friction that is present during a fluid air-to-air engagement. The living, breathing "man in the box" who is well versed and trained in threat tactics and procedures, operating within the confines of threat doctrine, and operating aircraft that closely resemble threat platforms provide the most accurate feedback on the success or failure of friendly tactics verses that threat. If U.S. aviators do not validate the assumptions of blue tactics against a threat representative adversary, then they will have a false sense of security with blue hardware and tactics. The 2004 Cope India exercise illustrated the point that assumptions left without

validation are dangerous and costly. Specifically, the adaptive capability of Indian Air Forces flying seemingly inferior former Soviet systems in a superior manner to overcome technological inequalities disproved many friendly threat assumptions.[46] If realistic training and tactics evaluation was a key factor in past successes against inferior airplanes even while retaining U.S. technological advantages, then training will become even more important as threat aircraft reach technological parity.

Even if the United States maintains technological superiority and BVR weapons employment capabilities continue to improve over those of threat nations, U.S. aviators still need live adversaries to remain proficient in both BVR and WVR air-to-air combat for several reasons. First, complex A/A environments degrade pilot situational awareness and unexpected merges may occur. Likewise, degraded systems, such as a loss of data-link or communications capabilities caused by jamming or component failure, and political rules of engagement restrictions may force visual identification of enemy aircraft, limiting aircrews' ability to employ weapons BVR. Forced merges caused by an inherent speed disadvantage in a "rundown" scenario are also possible for relatively slower airframes such as the F/A-18 and F-35. U.S. aircrews may also want to close within visual range to increase the probability of weapons success, based on factors such as kinematics, in scenarios where favorable merging conditions exist.[47] Thus, WVR maneuvering against live adversaries remains a training necessity.

Finally, since build-up time in future conflicts against near peer foes will not likely exist, Navy and Marine aircrews must be experienced and proficient in ACM. Because A/A tactical employment is a perishable skill, aviators must prepare to execute effectively on day one in order to ensure survival of aircrews and retention of aircraft. To this end, the Naval Air Command (NAVAIR) pre-deployment training plan (PTP) syllabus requires dissimilar air combat training

with adversary squadrons.[48] Clearly, at least from the Navy standpoint, DACT is a critical skill that aircrews must hone prior to deployment while dissimilar assets are available. In so doing, the Navy ensures that it does not have to relearn the costly lessons of Vietnam.

Current Navy Stance—Affordable, Sustainable, and Threat Representative

Background: Affordability/Strike-Fighter Shortfall

Due to a current and projected strike-fighter shortfall in the Navy and Marine Corps—that is, a deficiency in the number of current F/A-18s in all variants combined with future F-35B/Cs Joint Strike Fighters (JSFs)—it is unlikely that a budgetary windfall for adversary funding will occur. The 10 April 2009 Congressional Research Service (CRS) report for Congress addressed the Navy-Marine Corps strike-fighter shortfall this way:

> DON's inventory of strike-fighters currently falls short of the number that Navy officials state is required to fully support requirements for CVWs and MAWs, and the Navy is projecting that this shortfall will grow in coming years. The Navy projects that if no additional action is taken, a DON strike-fighter shortfall of about 15 aircraft in FY2009, to 50 aircraft in FY2010, and to a peak of 243 aircraft in FY2018. The projected strike-fighter shortfall is hoped to decrease after FY2018, but the DON will still have a gap of over 50 strike fighters in 2025. At its peak in FY2018, the projected DON strike-fighter shortfall will be 129 Navy strike-fighters and 114 Marine Corps strike-fighters.[49]

These numbers reflect an assumed additional Hornet airframe life extension to 8,600 hours through increased inspections, 10,000 hours through a $23 million per aircraft service life extension program within the Navy budget (for possibly up to 289 airframes), and F-35 procurement to proceed according to plan to a sustained rate of 50 aircraft per year.[50] Reduced Congressional funding will likely slow the ramp up of production numbers and increase the gap according to a 23 September 2010 CRS report on the Joint Strike Fighter program that stated,

> On September 16, 2010, the Senate Appropriations Committee funded 32 F-35s, 10 fewer than the Administration requested. The report on the House-passed version of the FY2011 defense authorization bill included language limiting

procurement to 30 F-35s pending certification that the F-35 had achieved certain testing parameters.[51]

Since this strike-fighter shortfall is both present and looming on the horizon for years to come, the DON should sustain some form of adversary capability that is not reliant upon blue airframes to preserve the longevity of current and future DON strike-fighters. Future JSF prevalence in fleet units makes this issue especially important both due to the limited numbers of JSFs (10 aircraft per squadron as opposed to the current 12 plane squadron construct) and its high average procurement unit cost of $113.6 million dollars, in constant FY2010 dollars.[52]

Sustainability

Sustaining the adversary fleet of the Navy and Marine Corps is a vital component of maintaining the United States' ability to gain and maintain air superiority, albeit indirectly. By reducing the burden upon fleet F/A-18s to provide Red Air, flight hours devoted to practical application of blue tactics increase, strengthening the proficiency of the airborne force. Additionally, if fleet airframes do not perform Red Air, then the number of fighters available for future conflicts increases. Thus, reduction or elimination F/A-18 use in the adversary role is central to the concept of sustainability. To do so, the DON must fund sustainment, upgrade, and possible purchase of additional less costly dissimilar aircraft, such as the F-5 and F-16.[53]

First, Navy F-16A/B models flown by NSAWC must be materially upgraded by 2013 or risk major structural damage. According to LT John Peterson, NSAWC adversary pilot and TOPGUN adversary subject matter expert (SME), NSAWC F-16s will be unable to fly due to safety concerns or airframes reaching fatigue limits in less than two years if the Navy fails to fund "Falcon UP" modifications within this fiscal year (FY2011).[54] These modifications will extend NSAWC F-16 airframe lifespan from 1800 to 3000 hours with the potential to reach 4000 hours at a cost of $4.3 million dollars in FY-13 and a total of $8.8 million dollars for all ten

NSAWC F-16A's. The Navy must sustain the NSAWC F-16s as the only dissimilar adversary aircraft in the Navy's inventory capable of replicating an advanced category IV threat aircraft,[55] and should make these modifications a high priority for this minimal funding.[56]

Second, F-5 fleet airframe structural component replacement must occur by 2015. As cited and graphically depicted in a Chief of Naval Operations, Director of Air Warfare, N88, Powerpoint presentation on the current and future Navy adversary force structure, "Without funding, F-5 inventory will begin to decline FY16 due to replaceable component fatigue. With funding for installations, [there is] 95% certainty the entire DON F-5 fleet [will remain] in service until FY2025."[57] If funded, these installations will cost the Navy $2.1 million dollars in FY13 and $10 million total to complete, a relatively cheap investment to keep aircraft flying in numbers, if not with upgraded capability.[58]

Threat Representativeness

As mentioned in the current adversary posture section, today's USN/USMC adversary fleet is far from representative (with the exception of the NSAWC F-16A/B and possibly the F/A-18E/F) of the category 4+, or "advanced threat" which is becoming widely proliferated or even the "percentage" category 4 threat aircraft seen employed today.[59] Although the current Marine F/A-18 Training and Readiness Manual (T&R) in many cases requires dissimilar threat representation in certain sorties, it does not specify the caliber or category of threat representation,[60] an observation indicative of the slight emphasis paid to the caliber of threat representation within the Marine Corps.

Likewise, the U.S. Navy has identified the obsolescence of its F-5 assets, and the lack of distinction within the T&R since, "the T&R does not capture adversary quality, *but* fleet input, analytic studies, and exercises all agree F-5 performance is unacceptably obsolete"[61] (Emphasis

added in original). Specifically, the 2010 DON Adversary Laydown brief identifies F-5 shortfalls in three areas: "Unable to simulate any current-generation threat weapons; Unable to present superior airspeed threat; Range and endurance limit ability for multiple tactical runs / regeneration."[62] Although the Marine Corps does not employ "double cycle" operations (flying two different sets of blue fighters in succession versus only one set of red adversaries that remain airborne to service both periods), the Navy routinely does. Yet, the relatively minimal fuel capacity of the F-5 limits its ability to double cycle, thus increasing the number of sorties to provide the same amount of training.

Furthermore, both the Navy and Marine Corps consider their F-5s as non-radar aircraft because although the F-5 does employ the APQ-159 radar, it cannot simulate modern Pulse-Doppler threats. Thus, the Department of the Navy provides sixty-two percent of its adversary capacity with non-radar aircraft.[63] In addition, the F-5's inherently limited radar capability causes trouble for the Red Air in setting up precise presentations and making accurate assessments of Blue Air actions. The non-representative radar signature of the F-5 also limits blue fighter courses of action based upon radar warning receiver indications.

Additionally, although not an F-5 specific deficiency, the DON adversary force as a whole is deficient in its electronic attack (EA) capability. Although most modern threat air forces employ some form of advanced EA, Navy and Marine tactical aircrews receive limited training in dealing with this threat capability, mainly due to a lack of red assets. Though the Navy does possess a few advanced capability (ACAP) jamming pods which are capable of replicating some modern digital radio frequency memory (DRFM) based airborne jammers, these are limited in numbers and generally reserved for use at Fallon, limiting the average fleet aviator's chances of training against it, especially a Marine pilot. Finally, combined with the fact

that the Navy estimates a 34% Red Air capacity versus requirement gap (including the benefits of a 33% double-cycle rate of Navy assets), the DON adversary force is deficient in both numbers and capability, falling far short of fleet "customer" defined requirements.[64]

ADVERSARY OUTLOOK

Hurdles

The United States adversary capability writ large has many obstacles to overcome on its way back to health. These obstacles include ingrained fiscal procedures that subjugate adversary programs to the periphery of budgetary forethought, an intransigent organizational mindset opposed to planning for the next conventional conflict involving aerial engagements, and a physical deficiency in both quality and quantity of Red Air assets. First, a shift in organizational culture must occur. Specifically, the United States Navy and Marine Corps cannot continue to ignore and inadequately fund adversary training programs in lieu of channeling funds to acquire the next most capable end-all, be-all blue system. Without adequate, cost effective adversary support, friendly assumptions will go untested and the DON will use more costly airframes faster than planned. Since the Department of Defense budget will continue to shrink in the coming years it is likely that the DON may once again overlook adversary requirements in favor of next generation technology development.[65]

Second, organizational mindset must additionally shift regarding the current and future threats. The Navy and Marine Corps' aviation branches focused on the wars in Afghanistan and Iraq for the last ten years and supporting counterinsurgency (COIN) fights from the air. Now, the organizations must focus on operational testing and tactics development and evaluation for the next fight. With nation-states such as China, Russia, and Iran developing and proliferating advanced capabilities in both airborne platforms (with associated early warning, surveillance,

and air-to-air weapons systems) and surface-to-air weapons systems, air superiority will assuredly be contested in any large scale future conflict the U.S. engages in.

The Russian PAK-FA (undergoing flight testing and operational evaluation) and China's J-20 (reportedly attained its first flight on January 10, 2011) are both 5th generation stealth fighters demonstrating that possible enemy aircraft are advancing in technological capabilities.[66] Potential threat nations such as China also have the capability to launch large numbers of older generation fighters to complement their front line assets complicating the airborne environment in which U.S. forces might operate. Thus, training against a threat representative adversary force implies both accuracy in quality and quantity. As Major Robert Heston, USAF, a former USAF Weapons School instructor, concluded in his 1977 report on specialized A/A combat training,

> Survival in the modern aerial battlefield will require intimate knowledge of the mission, and we may not have time to reorient our training after the battle has begun. Given the nature of the threat and the requirement for air superiority, we must have a significant air-to-air force capable of performing consistently with the highest degree of excellence. Even a few capable fliers trained in the best air-to-air fighters can carry out this mission with the highest probability of success.[67]

A third hurdle to overcome is conditionally improving the quality and quantity of the adversary fleet, the latter of which will become more important as the DON introduces the JSF in active service. Closing the current adversary quantity requirement gap will not only remain a priority, but will likely grow in importance (at least in numbers of adversaries required airborne simultaneously) once the JSF enters service, based upon findings in the F-22 Raptor community.[68] According to trends observed by the Navy's Adversary Requirements Officer, in general the F-22 has required more Red Air than current 4th generation blue fighters due to training for inferior force ratios.[69] Because U.S. air forces rely heavily on technology instead of numerical superiority to maintain air-to-air superiority, scenarios where U.S aviators are

outnumbered are likely.[70] Hence, DON adversaries badly need increases in the quantity and quality of airframes, which the Navy can acquire through several methods discussed hereafter.

Available Options

Blue Force Options

Two options exist that rely less on red force quantity or capability increases, but more on utilization of blue assets in Red Air roles. First, Marine aircrews can continue to utilize fleet aircraft for in-house Red Air and rely more heavily on blue/red swaps with sister services to overcome the Red Air shortfall if the sole Marine adversary squadron ceases to exist. As previously discussed, this option is almost certainly more expensive and diminishes returns in threat representativeness, slow relative speed, increased FLE, and lack of dissimilar training advantages such as visual identification (VID) drills. The second option involves a revision of the F/A-18 T&R manual to reduce the number of syllabus flights that require adversary support. By reducing the amount of air-to-air emphasis within the T&R, the current adversary support can close the fleet requirements gap simply through this revision. However, this requires that the U.S. inherently accept an increased amount of risk to aircrew survivability and a decreased ability to ensure future air superiority.

Simulator Upgrades

Simulators provide another solution to the Red Air dilemma. While U.S. fliers now rely more on technological advances to achieve superiority in the real world air-to-air arena, reliance is also increasing on technological solutions to achieve realistic training in a simulated environment. This solution is not as obvious, or cost effective, as it may seem. Historically, within the F/A-18 community, simulator technology has lagged technology installed in the actual aircraft. For instance, the current Super Hornet software load running in the Navy's simulator

building in Lemoore, CA is "18E%," a software load that is over 6 years old and far out of date with that loaded in fleet aircraft.[71] Likewise, time consuming reboots often plaque training events in the simulators due to frequent system crashes.[72] Additionally, threat replication in the simulators often lacks the fidelity of real threats and does a poor job simulating radar and RWR interface and EA employment threat capabilities. Since the Navy and Marine Corps will likely leverage the simulation option heavily in the future, the DON must keep synthetic training useful by mirroring current fleet software loads. To this end, funding contracts must include requirements for flight software revision and threat upgrades in the software to keep pace with actual threat capabilities.[73] Finally, simulators lack one key factor that should prevent them from becoming the sole solution to the Red Air problem—the physiological stress that an aviator experiences during actual flight, especially in a high g-force environment like ACM.[74]

Range Upgrades

Training range upgrades may also provide a cost effective option to enhance the ability of adversaries to accurate employ their aircraft and assess Blue Air effectiveness. Improvements to instrumentation in Tactical Aircrew Combat Training Systems (TACTS) ranges can aid Red Air in threat presentation setups and decision making simply through precise real-time control by adversary ground-controlled intercept (GCI) controllers, assuming that all players are adequately equipped with TACTS instrumentation. Although Red Flag at its inception in 1975 was largely a "plug and play" exercise that leveraged heavily upon existing Air Force range infrastructure, effectiveness assessment, and aggressor capabilities at Nellis AFB, the USAF wisely upgraded its capabilities in these three areas to preserve the realism of Red Flag.[75] For DACT to remain an effective and realistic training tool for naval aviators, the Navy and Marine Corps must follow suit. (See Appendix H for a discussion on Live, Virtual, and Constructive Options)

Aircraft Upgrades

The most obvious and cost effective option may seem to be improving the air-to-air capability of the current F-5 fleet through upgraded avionics and equipment. Because JSF training requires an adversary platform equipped with radar or some form of radar emulator, it makes sense to consider radar upgrades. Systems such as the APG-67 and GRIFO-F radars boast qualitative performance on the level of the current NSAWC F-16A/Bs equipped with APG-66 radars; yet, even these radars poorly replicate modern threats and hardly keep pace with the threat outlook. Additionally, this radar upgrade program cost would amount to $11.2 million dollars in FY2013 and a total cost of $87.0 million dollars, making it relatively expensive when compared to other possible upgrade programs.[76]

For instance, the F-5 lacks any form of recording capability for shot validation or aiding in accurate debrief of flight reconstruction. Additionally, no current DON adversary accurately simulates high off-boresight threat missile employment capabilities (with the exception of some Joint Helmet Mounted Cueing System (JHMCS) equipped NSAWC F/A-18E/Fs).[77] A limited helmet mounted cueing system with digital video mission recorder capability exists and can cheaply upgrade both F-5s and F-16s. For $1.5 million in FY2013 and a total cost of $6.4 million dollars, the DON could install this helmet mounted cueing system (HMCS) allowing off-boresight shot simulation and video recording capability in its F-5s and F-16s. This relatively inexpensive capability vastly improves the F-5's training utility especially for WVR weapons employment simulation and merge survival training for fleet aircrews.[78]

The Navy recognizes the need to sustain and upgrade its F-5 fleet. Vice Admiral Thomas Kilcline, commander, Naval Air Forces stated, "I see the F-5N as an adversary aircraft we will fly until the end of the next decade and, as such, it will need EA, ALR [radar warning receiver],

and an A/A radar that challenges our current and future fighters."[79] Although Admiral Kilcline stresses radar capability, it may be less important than upgrading the aforementioned smaller, cheaper systems in addition to providing a fighter-to-fighter data link capability to adversary forces that is available for purchase off the shelf. If the Navy and Marine Corps upgrade their F-5s with HMCS (with recorder capability), fighter-to-fighter data link, and an external ACAP jamming pod, the training value of these assets would increase exponentially over their current capability without costly and time consuming radar upgrades.

These cheaper systems provide adversary forces with the ability to set up accurate threat presentations employing advanced EA, simulate employment of passive weapons, and increase debrief validity and value while augmenting more capable platforms for relatively little cost. If nothing else, even without radar, keeping additional platforms airborne adds training value through sheer numbers for threat representative force ratios or for improving radar mechanics during sorting drills for Fleet Replacement Squadron (FRS) students.[80] NAVAIR may also conserve significant funds in this area alone, allowing for development of follow on systems that may be available in the future. Such systems include a radar emulator, to add value to Blue Air training in making decisions based on accurate RWR indications or an Infrared Search and Track System for better simulation of passive weapons employment.

Similarly, the Navy F-16A/B fleet requires upgrades to keep pace with the threat. Upgrading HMCS and adding ACAP pods will go a long way in adding training value. Additionally, the Navy should consider upgrades to active electronically scanned array (AESA) radars that are currently available for the F-16 which more appropriately mirror threat capabilities. Like those for the F-5, these radar upgrades are the most costly of options and the Navy may only need limited numbers for adequate replication of the threat while keeping a cost

efficient adversary force. Furthermore, according to Lieutenant Commander Scott Seeder, Navy Adversary Requirements Officer, the Navy is considering purchasing up to 20 additional low flight hour F-16A/Bs currently in storage at Davis Monthan AFB. The Navy can restore these aircraft for approximately $10 million each, providing 2,000 hours of useable life in Red Air roles—a wise step for the Navy.[81]

Contract Red Air Option

Outside contracted air provides a final alternative to increase Red Air capacity. However, this option is less suitable for a variety of reasons: the airframes contractors fly today—such as Kfirs and Hawker Hunters—typically lack modern threat capabilities; contractors have limited numbers of airframes; contract air is costly when compared to more capable F-5s and F-16s;[82] and concerns over contractor security clearances increase difficulties in employing them effectively. Thus, contract Red Air is not a viable option for truly increasing capability beyond augmenting capacity and EA capability by increasing numbers of aircraft and jammers (if so equipped) airborne.

RECOMMENDATIONS

The evidence presented strongly suggests that the United States Navy and Marine Corps maintain an adversary capability. This capability should comprise mostly dissimilar assets and focus on the accurate replication of threat air forces in order for fleet aircrew to maintain the training benefits of gaining experience and proficiency through DACT. Based upon current fleet T&R requirements and present adversary capacity to fulfill these requirements, adversary aircraft must not only improve in capability, but also increase in quantity. The DON adversary capability must remain cost effective while becoming more relevant (threat representative) and sustainable due to current Department of Defense fiscal constraints and forecasted continued

fiscal tightening. To this end, this paper recommends a combination of airframe upgrades, system upgrades, and simulator improvements.

The results of this examination support usage of simulators for everyday administrative flight training, emergency procedures, and basic tactical employment. Simulators provide critical repetition for fundamental radar employment concepts efficiently without reliance on adversary aircraft support and regeneration for multiple engagements. However, simulator capabilities must keep pace with both the threat and fielded fleet hardware and software upgrades to remain useful. In addition, the DON must maintain a live adversary capability to develop aircrews' decision-making skills against fluid, thinking adversaries, and for achievement and maintenance of A/A skills in the WVR arena.

This paper thus recommends that the Navy and Marine Corps fund upgrades to all DON F-5s in the areas previously mentioned as soon as possible to remain capable of presenting accurate threat pictures in representative numbers. Furthermore, the Navy should upgrade its NSAWC F-16s in needed areas to keep this airframe relevant as the only DON adversary aircraft truly capable of advanced aircraft threat simulation; likewise, the DON should also seek additional F-16s to increase the capacity of this critical airframe to perform Red Air missions for both the Navy and Marine Corps. Finally, even if a major shift occurs toward almost total reliance upon simulators, the DON must maintain a limited number of live, dissimilar adversary aircraft for the purposes of tactics development and validation, activities that the Navy and Marine Corps' weapons school commands, NSAWC and MAWTS-1 primarily conduct.

CONCLUSION

Since the advent of manned aerial flight, and its consequent introduction into the conduct of warfare, the side that possessed the capability to control the air enjoyed many advantages as it conducted the war on the ground below. Enemies of the United States learned this lesson in recent history, as the unchallenged airpower of the U.S. was an invaluable enabler for the successful conduct of ground operations. Unimpeded air supremacy like that possessed over Iraq and Afghanistan will not likely come at such little expense to U.S. airborne forces in future conflicts. To ensure the United States has the ability to gain and maintain air superiority versus an enemy possessing a modern air force employing advanced aircraft and tactics, U.S. pilots must be well versed in dissimilar air combat tactics and highly proficient in air combat maneuvering. Future air superiority will not be cheap and must be "paid forward" in advance of conflicts in order for U.S. aircrews—and ultimately, U.S. forces—to succeed.

It is time the United States Navy and Marine Corps attend to their intrinsic adversary force that they have neglected for too long. The Department of the Navy must not only sustain and upgrade its antiquated airframes, but also search for new technologies, capabilities, and capacity within the Red Air community to keep adversary programs relevant, affordable, and threat representative. In today's fiscally conservative environment, only through judicious utilization of scant resources will the Navy and Marine Corps maintain this invaluable preparatory tool for today's aircrew to succeed in tomorrow's air-to-air combat environment.

Appendix A: Adversary Origins—World War I and World War II

World War I

Although Dissimilar Air Combat Training (DACT) is a common practice among fighter aircrews from all United States services employing tactical aircraft today, it was not always the case. During World War I, early aviation on both sides focused mainly on reconnaissance and artillery spotting. As German and Allied spotting aircraft came into conflict with one another in the skies, the aircraft began to take on an offensive aspect. Armed with machine guns, German Fokker monoplanes attacked British and French aircraft employed in reconnaissance and soon dominated the western front.[83] The British Royal Air Force (RAF) responded in kind with the development and introduction of the de Havilland DH2 biplanes, forming the first allied fighter squadron, Number 24 squadron. The success of Number 24 Squadron in aerial combat versus the German Fokkers forced a subsequent redevelopment of fighter tactics by the Germans commanded by Oswald Boelcke.[84]

Boelcke quickly devised a program to determine the relative capabilities of Allied aircraft by rebuilding captured aircraft and flying them against his own aircraft. Once Boelke recognized the comparative strengths and weaknesses of each airframe, he then developed new tactics to pit German aircraft strengths against allied aircraft weaknesses. Allied forces also recognized the benefits of analyzing the performance characteristics of captured enemy aircraft and training against a dissimilar adversary, giving birth to the first specialized squadrons formed to develop air combat tactics. Aviators thus recognize actions during World War I as the birth of DACT.[85]

World War II

As in World War I, aviators quickly relearned the benefits of DACT and the consequent development of tactics to overcome a dominant dissimilar adversary in World War II when allied

forces in the Pacific confronted the venerable Japanese Zero. Japanese air superiority provided by the Zero was a problem for U.S. forces, which employed inferior F4F Wildcats, P-40 Warhawks, and P-39 Aircobras and British forces flying Hurricanes and Brewster Buffaloes. American fighter capability did not overcome this gap until the emergence of follow on aircraft such as the F4U Corsair, the P-38 Lightning, and the F6F Hellcat.[86]

Encountering the Zero first, Chinese air forces in 1940 reported that allied aviators should develop dissimilar tactics to defeat the Zero until production of the next generation of aircraft.[87] The Chinese hired retired U.S. Air Force Captain Claire Chennault, an advocate of innovation of advanced dissimilar tactics, as their aviation advisor. Instrumental in developing the air defense program against the Japanese,

> Chennault validated early Chinese reports regarding the Zero's performance and concluded that Allied aircraft would not be successful going head-to-head against the Zero. Chennault and his cadre of pilots known as the Flying Tigers developed aerial combat tactics to combat the Zero and later validated these against captured Japanese Zero's. Combat engagements using these tactics validated that the use of dissimilar tactics against a superior aircraft could be achieved.[88]

Such dissimilar tactics involved exploiting the one advantage of the P-40 over the Zero, the P-40's diving performance, to utilize hit-and-run attacks begun from a superior positional advantage based upon altitude, and led to many P-40 successes.[89]

To further advanc the DACT concept and apply it to the F4F Wildcat, U.S. Navy Lieutenant Commander Jimmy Thach developed his own dissimilar tactics in 1941, in advance of the U.S. intervention into the war in the Pacific. Thach lacked the benefit of acquired Japanese aircraft, and was unable to find an allied aircraft with capabilities similar to the Zero. Thus, Thach simulated his best estimate of performance differences between the F4F and the Zero by pitting two F4F's against each other with different throttle allowances to validate his tactics. Thach tested his new weaving tactic, and validated its effectiveness against an adversary

aircraft with superior performance by using an unrestricted F4F "aggressor" simulating a Japanese Zero and an F4F limited to 50 percent throttle capability to simulate the Wildcat's power deficiency.[90] This method of self-imposing limitations on pilots and aircraft laid the foundation for replication of threat capabilities utilized by Adversary squadrons and fleet aviators who have performed the aggressor role through today.

Appendix B: USAF Analysis of A/A results of the Vietnam Conflict

Although believing that a slightly different problem—the lack of awareness of impending attack by an unseen foe—was the root cause of decreased aircrew performance in Vietnam, the U.S. Air Force came to a similar solution as the Navy to improve aircrew performance. The Air Force established a better training program that emphasized DACT, especially with aircraft of inferior size that more closely resembled the visual signature of the MiG aircraft U.S. fighters encountered in Vietnam. Since few USAF aircrew had fought against a dissimilar adversary prior to actually facing one in combat, the aircrew lacked experience in fighting an aircraft of different size and performance that was employed based on different doctrine. Additionally, the Air Force determined that the enemy generally gained a "tally" or visual identification before USAF aircrews. This finding reinforced the statistic that 58 percent of USAF aircrews shot down in Vietnam were completely unaware of the presence of the enemy aircraft since their eyes were not accustomed to scanning for smaller aircraft.[91]

Similarly, a poll of USAF aircrews during Vietnam found them to be relatively ignorant of their enemy counterpart; Air Force pilots lacked knowledge of enemy tactics, aircraft capabilities, armament, lifestyle, and flight training regimen. Although the (U.S. Air Force) Fighter Weapons School placed emphasis in academic instruction on threat pilot tactics and aircraft capabilities, USAF veterans of the air war in Vietnam recognized that the Air Force needed a program that emphasized more than academic study alone.[92]

Appendix C: Red Flag

The report of project Red Baron also identified three significant trends that led to recommending the formation of aggressor squadrons. Notably, the report found that multi-role fighter units were not proficient in any of the wide variety of missions they were supposed to perform and that pilots were unaccustomed to looking for smaller, more agile aircraft because they had been fighting their own, larger aircraft. The report also noted that, "USAF pilots were unfamiliar with enemy fighter tactics and aircraft capabilities, and did not develop or train with tactics intended to exploit enemy weaknesses."[93] In addition to recognizing the value of training against a smaller, dissimilar adversary to hone a pilot's air-to-air skills, the Air Force also wisely recognized the true benefit of DACT—the increased survival rate of relatively inexperienced aircrews in combat (and the preservation of the costly airframes they flew).[94]

Similarly, an analysis conducted by the Litton Corporation that studied air combat trends from World War I to Vietnam concluded that a pilot's first ten missions were a critical period as his chances for survival went up exponentially after that.[95] Analyst Herbert K. Weiss reinforced this finding through a systems analysis exercise in which he attempted to define how crucial pilots' skill and experience were to their survival rate in combat. Weiss concluded through his observations that a pilot's probability of surviving a decisive aerial engagement "improved 20 fold from his first to his fifth mission."[96] (See Appendix D) Putting this concept into action, the Air Force created a two week exercise known as "Red Flag" geared toward seasoning inexperienced pilots in a realistic air combat training environment against dissimilar adversaries that began on November 27, 1975. This exercise simulates a junior pilot's first ten combat missions to experience the rigors of air combat and offers a forum for more experienced flight leads to gain valuable flight leadership experience and tactics development training.[97]

Appendix D: Herbert K. Weiss Systems Analysis[98]

SUMMARY OF A SYSTEMS ANALYSIS EXERCISE BY HERBERT K. WEISS

Drawing upon a limited number of World War I and World War II engagements, Weiss attempted to define just how critical pilot skill was. He derived the following approximation:

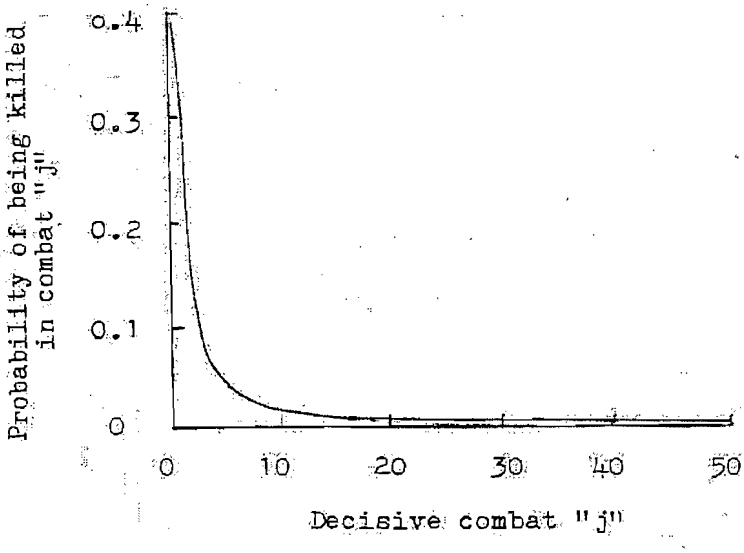
$P_j = K_{j-1} / (S_j + K_{j-1})$, in which

K_j = the number of pilots killed in action by enemy aircraft with some number of kills, j;

S_j = the total number of pilots living or dead with at least the score j; and

P_j = the probability that a pilot will be killed in his jth decisive combat (one in which a plane is downed).

Weiss compared P_j with the number of decisive combats and observed that a pilot's probability of living through a decisive engagement improved 20 fold from his first to his fifth mission.



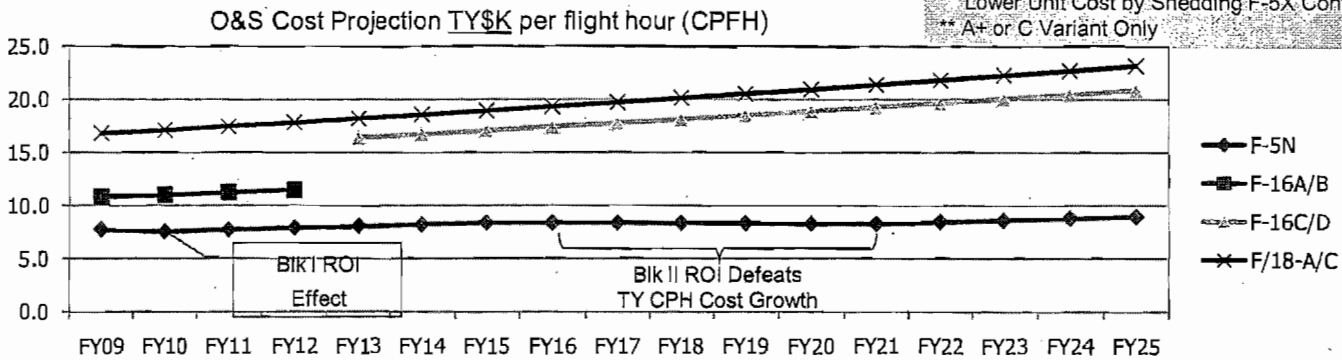
67

Appendix E: Northrop Grumman Cost Estimates[99]

Relative Cost Matrix

TMS	Approx. Recap Cost per A/C	Common Navy Support Infrastructure	O&S CPH Ranking	S/F Shortfall Risk	Dissimilar	Sustainable through 2025
F-5N Blk II	$3.5M*	Y	Lowest (Baseline)	N	Y	Y
FA-18A/C	N/A	Y	225% of F-5N	Y	N	Y**
F-16A/B	N/A	N	130% of F-5N	N	Y	N
F/16 C/D	$50M	N	200% of F-5N	N	Y	Y

Denotes high risk
* Lower Unit Cost by Shedding F-5X Config
** A+ or C Variant Only



O&S Savings Over 5 Yrs Can Help Self-finance the F-5N Blk II

8

KEY:

ROI- Return on Investment

O&S- Operations and Support

Appendix F: CNO Cost Per Hour Comparison[100]

Adversary Cost Per Hour Comparison

	F-5N/F	F-16A/B	Type III CAS	F/A-18 (AC)	F/A-18 (RC)	Type IV CAS	F/A-18 (NSAWC)
AVDLR	$1,452.65	$579.55	NA	$3,395.95	$3,914.93	NA	$3,161.08
Consumables	$440.33	$215.91	NA	$1,257.66	$1,419.52	NA	$1,181.82
Fuel	$1,216.80	$1,575.98	$1481.85	$2,520.26	$1,992.34	$1922.40	$2,620.93
Contract Maintenance	$2,714.02	$4,901.87	$6593.15	$33.35	$0.00	$8119.60	$3,043.57
Total CPH	$5,823.79	$7,273.31	$8075.00	$7,201.21	$7,326.79	$10042.00	$10,007.40

- Both supersonic, non-PD radar equipped.
- Both capable of DRFM EA.
- CAS limited to 180° of turn post-merge.
- Fair comparison unless replacement of adversary assets accompanied by RIF.

Data based on N43-provided FY-10 budgeted FHP (OP-20 v2478) & PMA-207 calculated CAS costs, Jul 10.

15

KEY:

CAS- Contract Air Support

AC- Active Component

RC- Reserve Component

PD- Pulse-Doppler

Appendix G: Dr. Daniel Haulman's Findings

In 2002, Air Force Historical Agency historian Daniel Haulman investigated the role of U.S. air power in the conflicts the U.S. engaged in during the 1990s (1991-Iraq/Kuwait; 1995-Bosnia/Serbia; 1999-Kosovo). In his review, Haulman recognized the value of air superiority and argued that air power played a larger factor in the victories U.S. forces achieved in these conflicts than in previous ones largely due to U.S. control of the air. This air control was the direct result of the USAF's flawless combat record in air-to-air engagements in the last decade of the twentieth century. Haulman supports this claim stating that, "during the 1990s, U.S. Air Force aircraft shot down 48 enemy aircraft. In the same decade, enemy pilots shot down not one U.S. Air Force aircraft."[101] Yet, Haulman emphasized the importance of training over mere technological advantage in these USAF A/A victories. In fact, Haulman cited deliberate Air Force overhaul efforts in training of fighter pilots in air-to-air combat in the years since Vietnam, including the establishment of Red Flag, as critical components to USAF success in the 1990s in addition to being better equipped materially.[102]

Appendix H: Live, Virtual, and Constructive Option

Another option has surfaced that combines physical platforms with simulated entities to provide threat replication. The U.S. Department of Defense Training Transformation Implementation Plan FY2006-FY2011 espouses integrating environments, such as the Joint National Training Capability, to conduct joint exercises against free-playing opposing forces (OPFOR). These exercises are "...based on an integrated and distributed environment of live, virtual, and constructive [(LVC)] simulations..."[103] Although not specifically focused on air operations, this capability for "training, experimentation, and mission rehearsal" has "achieved initial operating capability for a global, multinational network of constructive computer simulations, man-in-the-loop virtual simulators, and live forces at instrumented ranges."[104] This system is largely in its infancy with respect to air-to-air combat, but does highlight a few areas where implementation of this concept will better the adversary force in light of technology and the move toward increasing simulation. With the JSF capability to program digital radar entities into its threat simulation modes, the leap to conducting LVC exercises seems the next logical step and will largely depend upon the ability to integrate live Red Air assets with simulated radar returns in a seamless, realistic manner.

Endnotes

[1] Sun Tzu, *The Art of War*, Samuel B. Griffith, ed. and trans. (New York: Oxford University Press, 1971), 83.

[2] The term "dissimilar" implies an aircraft different from the one fleet aviators fly. For example, an F-16 is dissimilar to an F/A-18 because it is a different fighter aircraft, although they are both U.S. made aircraft. This term also applies to foreign built aircraft when flown against U.S. fighter aircraft.

[3] United States Marine Corps, Marine Aviation. *USMC Adversary Requirements.* Powerpoint. (Washington, March 12, 2009), slide 2; Headquarters United States Marine Corps. *FA-18 Training and Readiness Manual; NAVMC 3500.50A, (*Washington: Headquarters United States Marine Corps, March 2010).

[4] The U.S. Navy and Marine Corps typically use the term "Adversary" to describe aircraft performing threat replication roles. The U.S. Air Force typically refers to aircraft in this role as "Aggressors." Though many aviators often use the terms interchangeably, this discussion uses the term "Adversary" to describe aircraft and pilots executing threat tactics.

[5] Rick Llinares and Chuck Lloyd, *ADVERSARY: America's Aggressor Fighter Squadrons.* (Atglen, Pennsylvania: Schiffer Military History, 1999), 10. For a more in depth look, see Appendix A.

[6] Llinares and Lloyd, 10. For a more in depth look, see Appendix A.

[7] Llinares and Lloyd, 11.

[8] To begin engagements under conditions that favored their aircraft's strengths, Sabre pilots quickly learned to alter their tactics to lure the enemy MiGs down to the altitude at which the Sabre optimally performed. Llinares and Lloyd, 11.

[9] Reports vary on the actual overall kill ratio, but the general consensus is that the Navy scored a 10 to 1 kill ratio while the Air Force did better at 14 to 1, largely due to its predominance of assigned air-to-air missions. Barry K. Wood, Maj, USAF, *Will Aggressor Squadrons be Needed in the Future?* Masters of Military Art and Science Thesis, (Fort Leavenworth: U.S. Army Command and General Staff College, 1979), 11; Llinares and Lloyd, 11.

[10] Llinares and Lloyd, 11.

[11] Robert K. Wilcox, *Scream of Eagles.* (New York: Pocket Star Books, 2005), 47-48; Alexander Berger, Major, USAF, *Beyond Blue 4: The Past and Future Transformation of Red Flag.* Masters Thesis, Air Command and Staff College, Air University, (Maxwell Air Force Base, Alabama: Air University, April 2004), 1.

[12] Llinares and Lloyd, 11, 14.

[13] Almost 600 missiles were fired by Navy and Air Force pilots between 17 June 1965 and 17 September 1968, with performance statistics indicating a probability of achieving one kill for every ten firing attempts (10% effectiveness) when employed in an environment similar to that in Vietnam. Naval Air Systems Command. *Report of the Air-to-Air Missile System Capability Review July - November 1968 (U).* Technical Report, U.S. Department of the Navy, (Washington: Naval Air Systems Command, 1 January 1969), 1.

[14] Naval Air Systems Command, 1; and Llinares and Lloyd, 14.

[15] Naval Air Systems Command, 1-38; and Llinares and Lloyd, 14.

[16] The findings of the report also stressed the accurate performance evaluation of both missiles and aircrew as "crucial to training progress and systems performance improvement actions." To this end, the report recommended gathering telemetry data on all missile firings, in combat and training, as well as conducting ACM training on an instrumented range to improve performance materially. Likewise, the Ault report recommended making improvements to training aids such as movies, slide shows on AIM-9 and AIM-7 systems, and a "means of consolidating, coordinating, and promulgating the doctrine, lore, tactics, and procedures for fighter employment" to reverse the trend of gradual loss of expertise in the field of fighter weapons employment. Naval Air Systems Command, 21, 22, 35-37.

[17] Naval Air Systems Command, 37.

[18] Llinares and Lloyd, 14.

[19] Llinares and Lloyd, 14.

[20] Llinares and Lloyd, 15.

[21] Llinares and Lloyd, 15.

[22] C. R. Anderegg. *Sierra Hotel: Flying Air Force Fighters in the Decade After Vietnam.* (Washington, DC: Air Force History and Museums Program, 2001), 73; and Wood, 16.

[23] Llinares and Lloyd, 15.

[24] Project Red Baron II: Air to Air Encounters in Southeast Asia, Volume 1, p. 21, (USAF Tactical Fighter Weapons Center, Jan 1973), quoted by Berger, p. 4.

[25] Llinares and Lloyd, 15.

[26] Wood, 18.

[27] Fighter aircrews commonly refer to aircraft flown by pilots executing adversary roles as "Red Air".

[28] Rick Llinares. "VMFT-401: Adversary Tactics Experts." *Naval Aviation News*, (January-February 2002, pp. 10-15) 10.

[29] LT John Peterson, phone interview by Maj Kevin Campbell. *NSAWC N7 Adversary Subject Matter Expert* (January 13, 2011).

[30] Information derived from author's personal exercise involvement.

[31] Additionally, TOPGUN instructors fly the Naval Strike and Air Warfare Center (NSAWC) owned F-16A/B and F/A-18A/B/E/F in the adversary role. The Navy uses the NSAWC jets during Air Wing Fallon, the TOPGUN course, and to augment VFC squadron presentations for SFARP events, much like the USAF's 64th and 65th Aggressor Squadrons do during Red Flag, although these Navy assets do not technically belong to an adversary unit. Also, VFA-204, a Navy reserve F/A-18 unit based in New Orleans, LA flies 40-50% of its sorties in a Red Air capacity mainly in support of Training Support Wing events, though not chartered as an adversary unit. Peterson interview.

[32] Peterson interview.

[33] Llinares, "VMFT-401: Adversary Tactics Experts," 10-15; Author has extensive past interaction with VMFT-401.

[34] Aircraft that lacks external tanks or stores, which increase drag and radar cross section.

[35] Peterson interview.

[36] *USMC Adversary Requirements.* Powerpoint, slide 2.

[37] Peterson interview.

[38] LCDR Scott Seeder, USN, interview by Maj Kevin A. Campbell. *N-88 Adversary Requirements Officer* (Washington, D.C., December 28, 2010); Northrop Grumman. *F-5N Program Overview.* Adversary Powerpoint Briefing, Irregular Warfare, National Irregular Warfare Center, (Washington : Northrop Grumman), slide 5. Powerpoint provided by LtCol W. Kyle "Grease" Magrisi, HQMC Aviation, APW-31, on December 9, 2010.

[39] Secretary of Defense Robert Gates recommended cancellation of the EFV program on January 6, 2011 and General James Amos, Commandant of the Marine Corps, consequently terminated the program. Office of the Assistant Secretary of Defense (Public Affairs). *Statement by the Commandant of the Marine Corps Gen. James Amos on Efficiencies.* News Release, Office of the Assistant Secretary of Defense (Public Affairs), (Washington: U.S. Department of Defense, January 6, 2011).

[40] Although some Navy Briefings compare F-5 cost per flight hour (CPFH) at $5823.79 to an F/A-18 CPFH of $7201.21, the comparison is inexact because contract maintenance cost is associated with the F-5 CPFH, while the comparison does not account for F/A-18 maintenance costs. Because enlisted Marines provide most F/A-18 maintenance instead of contractors, the comparison skews the actual CPFH. Seeder interview and Northrop Grumman, slide 8.

[41] Peterson and Seeder interviews.

[42] Congressional Budget Office. *Strategies for Maintaining the Navy's and Marine Corps' Inventories of Fighter Aircraft.* A CBO Report, Washington: Congressional Budget Office, Congress of the United States, May 2010, 10; Peterson and Seeder interviews.

[43] See Appendix G for more on Air Force A/A victories in the 1990's. Berger, 5-6.

[44] Colonel Gregory Fontenot, USA (Ret), and Colonel Darrell Combs, USMC(Ret). "Fighting Blue: Why First Class Threat Emulation is Critical to Joint Experimentation and Combat Development." *American Intelligence Journal*, Summer 2008), 24.

[45] Dr. Daniel L. Haulman, *No Contest: Aerial Combat in the 1990s.* Thesis, (Maxwell AFB, AL: Air Force Historical Research Agency, 2002), 2.

[46] Although USAF F-15Cs that took part in Exercise Cope India 2004 were limited in the tactics and capabilities that they were allowed to use and thus their performance was hampered, the important point is that many assumptions as to how the Indian Air Force would tactically employ its assets were refuted through this real world validation. David A. Fulgham, "USAF Explains 'Cope India' Results." *Aviation Week and Space Technology*, (Elmendorf AFB, Alaska: October 04, 2004), 50-52.

[47] Director Air Warfare, N88. *2010 DON Adversary Laydown.* Powerpoint Presentation, (Washington: Department of the Navy-Chief of Naval Operations, 2010) accessed during Seeder interview.

[48] Seeder interview.

[49] Christopher Bolkcom, *Navy-Marine Corps Strike-Fighter Shortfall: Background and Options for Congress.* CRS Report for Congress, (Washington: Congressional Research Service, April 10, 2009), 2; Congressional Budget Office, 10.

[50] Congressional Budget Office, 10; Bolkcom, 2-3.

[51] Evidence of the increase of the severity of this shortfall is also present in a Pentagon issued Acquisition Decision Memorandum (ADM) dated February 24, 2010 that did not directly address maximum production rate

levels or when they would be achieved, but did slip full-rate production to November 2015. Jeremiah Gertler, *F-35 Joint Strike Fighter (JSF) Program: Background and Issues for Congress.* CRS Report for Congress, (Washington: Congressional Report Service, September 23, 2010), summary, 8.

[52] Gertler, 9.

[53] Peterson interview.

[54] Peterson interview.

[55] Although TOPGUN is phasing out the threat category system historically used to describe aircraft performance characteristics and technologic capabilities, the categories of aircraft capabilities are still widely used. This paper uses the term Category IV Aircraft to describe a relatively modern aircraft with sophisticated avionics, radar capabilities, supersonic flight capability, and excellent handling often provided by fly-by-wire flight controls or high lift devices. For example, current F/A-18 and F-16 aircraft are representative of this category of aircraft.

[56] Peterson interview and *2010 DON Adversary Laydown.*

[57] Seeder interview and *2010 DON Adversary Laydown.*

[58] Seeder interview and *2010 DON Adversary Laydown.*

[59] TOPGUN is currently replacing the aircraft category system in its vernacular to reflect emerging threat technologies. Instead of the traditional category system, TOPGUN is instituting the term "advanced threat aircraft" to describe newer than 4th generation aircraft or a more capable than category 4 aircraft. Likewise, the term "advanced EA" reflects modern DRFM based jammers possessing significantly more capability than older legacy systems.

[60] Headquarters United States Marine Corps. *FA-18 Training and Readiness Manual, 2-118.*

[61] *2010 DON Adversary Laydown.*

[62] *2010 DON Adversary Laydown.*

[63] *2010 DON Adversary Laydown.*

[64] *2010 DON Adversary Laydown.*

[65] The Secretary of Defense publicly announced on January 6, 2011 the reduction of the DOD budget by 78 billion dollars over the next five years. Fred Kaplan, "Trimming the Pentagon's Sails—Secretary Robert Gates' dramatic (but limited) plan to cut defense spending ." *Slate, War Stories: Military Analysis.* January 6, 2011. http://www.slate.com/id/2280254/ (accessed January 21, 2011).

[66] Multiple open source documents and news reports on recent flights of China's J-20 fighter and Russia's F-50 PAK-FA fighter support that these countries are producing aircraft with increasing performance, stealth, and tactical employment capabilities. Chinese and Russian fighter aircraft inventories are expanding while U.S. fighter aircraft inventories are shrinking due to delays in JSF production and the retirement of aging fourth generation fighters. Bolkcom, 2-3.

[67] Major Robert A. Heston, USAF, "Specialized Air-To-Air Combat Training." *Air University Review,* (September-October 1977), 6.

[68] *2010 DON Adversary Laydown.*

[69] Seeder interview.

[70] The Marine Corps will replace a squadron of twelve F/A-18s with a squadron of ten F-35Bs based on the logic that through superior weapons systems (radar upgrades, stealth characteristics, improved missile technology) and an increased maintenance readiness level, ten F-35 airframes will be able to accomplish what twelve F/A-18s can today.

[71] This information is accurate at time of final draft. Simulator upgrades are forthcoming to mirror fleet capability at H5E. Peterson interview.

[72] The author bases this statement on extensive simulator usage at MCAS Miramar through July 2010. Almost every simulator event requiring linking more than one simulator together experienced delays at some point for at least fifteen minutes and sometimes for as long as an hour, effectively ending the event. About one in every four simulator events that integrated four simulators linked together was interrupted when one of the four simulators would fail to integrate, crash, or "fall out" of the integrated environment.

[73] Peterson interview.

[74] Because there is no g-force imposed on an aviator's body in the simulator, the effects of reduced visual acuity and the increased physical demands of performing an anti-g straining maneuver under heavy g-forces in flight are not experienced.

[75] Berger, vii.

[76] Seeder interview and *2010 DON Adversary Laydown.*

[77] Seeder interview and *2010 DON Adversary Laydown.*

[78] Seeder interview and *2010 DON Adversary Laydown.*

[79] Northrop Grumman, slide 5.

[80] Peterson interview.
[81] Seeder interview.
[82] See Appendix F for Type III and Type IV Contract Air Support (CAS) cost comparison. *2010 DON Adversary Laydown.*
[83] Llinares and Lloyd, 10.
[84] Llinares and Lloyd, 10.
[85] Llinares and Lloyd, 10.
[86] Llinares and Lloyd, 10.
[87] Llinares and Lloyd, 10.
[88] Llinares and Lloyd, 10.
[89] Llinares and Lloyd, 10.
[90] Llinares and Lloyd, 11.
[91] Anderegg, 71.
[92] Anderegg, 73.
[93] Berger, 2-3.
[94] Berger, 1.
[95] Berger, 3.
[96] Wood, 67.
[97] Berger, 5-6.
[98] Wood, 67.
[99] Northrop Grumman, slide 8.
[100] *2010 DON Adversary Laydown.*
[101] Haulman, 2.
[102] Haulman, 2-3.
[103] Director, Readiness and Training Policy and Programs. *Department of Defense Training Transformation Implementation Plan FY2006-FY2011.* DoD Plan, (Washington: Office of the Under Secretary of Defense for Personnel and Readiness, February 26, 2006), 13.
[104104] Director, Readiness and Training Policy and Programs, 13-14.

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